

# Prophylactic Drug Treatment of Migraine in Children and Adolescents: An Update

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**Abstract** Migraine as a highly disabling pain condition influences the daily activities of those affected, including children and adolescents. The pathomechanism of migraine is not fully understood, and the different types of prophylactic antimigraine drugs that are applied are not specific for migraine. There is a need for preventive treatment in the event of frequent migraine attacks, an impairment of the quality of life, severe accompanying or aura symptoms, and the failure of acute drug treatment. The following pharmacological classes are recommended: antidepressants, antiepileptics, antihistamines, beta-adrenergic receptor blockers, and calcium ion channel antagonists, besides onabotulinum toxin A and nutraceuticals (butterbur). The most urgent goal as concerns pharmaceutical innovation is the development of pathomechanism-based antimigraine drugs and personalized therapy tailored to the children and adolescents.

**Keywords** Antidepressants · Antiepileptics · Antihistamines · Beta-adrenergic receptor blockers · Butterbur · Calcium ion channel antagonists · Efficacy · Migraine · Onabotulinum toxin A · Pediatric · Prophylactic · Safety · Therapy · Tolerability

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## Introduction

Migraine is a highly devastating neurovascular primary headache disorder that can affect subjects from childhood onwards [1, 2••].

The Headache Classification Committee of the International Headache Society (IHS) [3] has classified migraine into subtypes: migraine without aura, migraine with aura, chronic migraine, complications of migraine, probable migraine, and episodic syndromes that may be associated with migraine. The earlier name of this last subtype was childhood periodic syndromes that are commonly precursors of migraine [3]. Episodic syndromes that may be associated with migraine are further subdivided: recurrent gastrointestinal disturbance, cyclic vomiting syndrome and abdominal migraine, benign paroxysmal vertigo, and benign paroxysmal torticollis [3]. In young patients, migraine may occur with or without aura, and there may be an increased risk of the development of either of these disorders [3]. A recent retrospective study demonstrated that the prevalence of episodic syndromes that may be associated with migraine was 5.6 % [4]. The most frequent types of migraine are migraine without aura and migraine with aura. The typical clinical features are a duration of 4–72 h, a unilateral localization, a pulsating quality, and a moderate to severe intensity, worsening in response to routine physical activity, and usually combined with nausea, vomiting, and/or photophobia and phonophobia as concomitant symptoms of the headache [3]. In the event the occurrence of migraine aura, visual, sensory, or other central nervous system symptoms develops gradually and temporarily, usually preceding the headache phase [3]. Chronic migraine, one of the devastating subtypes of migraine, has a considerable influence on the quality of life, even in young patients [5, 6]. By definition, chronic migraine is the persistence of headache for at least 15 days

per month (migraine quality on at least 8 days) and for at least 3 consecutive months [3].

In pediatric migraine patients, the duration of the migraine attack may be shorter, the location of the pain is often bilateral, and abdominal pain, nausea, and vomiting are more frequent [7•]. The diagnosis of migraine in children and adolescents is therefore rather difficult, and the IHS diagnostic criteria are broader than in adults [7•, 8].

The importance of migraine in childhood is reflected by the fact that majority of the headache cases observed in the pediatric emergency department involve migraine [9]. Epidemiological data have revealed that 40 % of headaches are primary headaches, 75 % of these cases being migraine [9]. Clinical studies have demonstrated that the prevalence of migraine increases with age [1, 10], 3 % or less in those up to 7 years old, 11 % among 11 year olds, and 23–28 % in adolescents (13–18 years old) [1, 10]. In a large cohort of children, the prevalence of migraine proved to be 10.1 % and that of migraine with aura 1.6 % [11]. The prevalence of migraine depends on the age and the gender. The sex ratio of migraine patients is 1:1 (boys:girls) in childhood, the ratio subsequently increasing with the progression of age to 1:3 (males:females) [11]. The mean age of onset of migraine is 7.2 years in boys and 10.9 years in girls [1].

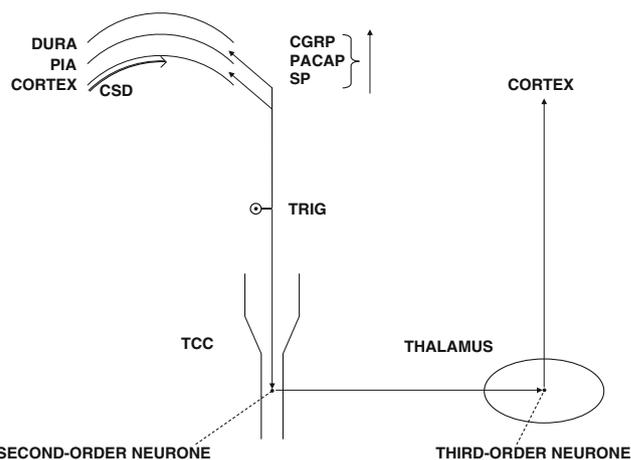
The pathomechanism of migraine has not been clearly elucidated, but activation and sensitization of the trigeminovascular system and distinct neuropeptides are deeply involved [12–15] (Fig. 1).

In consequence of the lack of knowledge, the precise pathogenesis of the initiation and the recurrence of migraine attacks, specific antimigraine prophylactic treatment is not available [17–20]. In everyday pediatric clinical practice, the recommended drugs for the prevention of migraine headache attacks are antidepressants (amitriptyline, AMI, and nortriptyline, NOR), antiepileptics (valproates, VALPs; topiramate, TOP; levetiracetam, LEV; zonisamide, ZON; and gabapentin, GBP), antihistamines (cyproheptadine, CYP), beta-adrenergic receptor blockers (propranolol, PROP), and calcium ion channel antagonists (flunarizine, FLUN) [7•, 21••]. Onabotulinum toxin A (OBOT-A) has recently been applied for the alleviation of chronic migraine in children and adolescents [22–24], and butterbur may be mentioned as a nutraceutical.

This review discusses the drugs currently used in the preventive therapy of migraine in children and adolescents.

### Prophylactic Drug Treatment in Pediatric Migraine

The indications of prophylactic migraine therapy include a high frequency of migraine attacks, an impairment of the quality of life and of the regularity of school attendance, the ineffective, not tolerated, contraindicated or overused acute



**Fig. 1** Scheme of the activation of the trigeminovascular system. The putative mechanism of activation of the sensitization of the trigeminovascular system is the following. The process of cortical spreading depression (CSD), a slowly propagating wave of neuronal and glial depolarization, activates trigeminal nociceptors. Activation of meningeal afferents leads to the release of CGRP, SP, and PACAP via the peripheral branch of the trigeminal pseudounipolar neurons. The released substances may promote neurogenic inflammation in the cerebral dura mater and lead to the activation and sensitization of peripheral meningeal nerve terminals, the nociceptors. The consequences of the peripheral sensitization include the central sensitization of the second-order neurons in the trigeminocervical complex (TCC) as well as that of the third-order neurons in the thalamus. Modified from Ref. [2••, 16]. Abbreviations: *CGRP* calcitonin gene-related peptide, *CSD* cortical spreading depression, *PACAP* pituitary adenylate cyclase-activating polypeptide, *SP* substance P, *TCC* trigeminocervical complex, *TRIG* trigeminal ganglion

management of headache attacks, or the presence of complex and severe accompanying symptoms or long uncomfortable aura symptoms [1, 7•, 17, 18]. The fundamental aims of antimigraine treatment are a decrease of the attack frequency by at least 50 % within 3 months and a diminution of the duration and intensity of the head pain [1, 18]. Although around one-third of adolescents need prophylactic antimigraine therapy, only 10–19 % are offered it [25]. For this special population, the parents or other family members should be educated as to the effects and possible adverse events (AEs) of the drugs and the drug titration and dosing schedule [26••]. Avoidance of the side-effects of the drugs demands slow titration (4–12 weeks), and the treatment period is suggested to be at least 6–8 weeks [26••]. In general, it is very important that the pharmacological treatment of young migraine patients should be accompanied by psychological support for.

### Antidepressants

#### *Amitriptyline*

AMI, a tricyclic antidepressant, has a multiple mode of action, which includes the blockade of norepinephrine and serotonin

reuptake, together with anticholinergic, histaminergic, and gamma-aminobutyric acid (GABA)-ergic effects [27, 28]. AMI influences the antinociceptive function via the activation of the adenosine A1 receptor and enhances neuronal sensitivity to substance P (SP) [20].

In the prophylactic treatment of pediatric migraine, AMI is one of the most widely used pharmacons despite the performance of only a low number of randomized clinical trials. A recent large academic hospital study revealed that AMI was the most common preventive medication prescribed to pediatric patients with migraine either with or without aura [29]. In a study where low-dose AMI or PROP was added to non-pharmacological therapeutic measures (e.g., relating to sleep hygiene, dietetic and lifestyle recommendations, or sun exposure), it was concluded that the both two drugs were equally effective in reducing the frequency of pediatric migraine [30]. A double-blind placebo-controlled multicenter comparative effectiveness study of AMI and TOP is ongoing (Childhood and Adolescent Migraine Prevention Study, CHAMP), with the aim of a 50 % reduction in migraine frequency in children and adolescents as primary outcome [31]. The first results are planned to be published in 2016. A prospective trial has led to the finding that supplementary vitamin D therapy in addition to AMI significantly reduces the number of migraine attacks in pediatric migraine patients [32]. A randomized clinical trial focusing on the effects of cognitive behavioral therapy (CBT) plus AMI versus headache education plus AMI in chronic migraine pediatric patients proved that the reduction in the number of headache days was superior in the CBT plus AMI group [33].

The recommended dose of AMI is 10–150 mg qhs (“every night at bedtime”) (at most 1 mg/kg/day) [7•]. The reason for the bedtime dosing is the somnolence that occurs as one of the most common side-effects of the drug [26••, 34]. Other frequent AEs are dizziness, constipation, increased appetite, and weight gain [7•]. AMI is preferred in view of its relatively favorable side effect profile and dosing regime [34]. The recommendation levels of migraine prophylactic drugs are based on the reports of the Scientific Task Force of the European Federation of Neurological Societies and the Quality Standard Subcommittee of the American Academy of Neurology and the American Headache Society [35, 36]. The recommendation level of AMI: Class IV, Level U [26••] (Table 1).

### *Nortriptyline*

In actual medical practice instead of AMI may be replaced by NOR, which has a lower sedative effect, but mention must be made of its significant potential cardiac side effect (arrhythmia) [7•, 26••]. The recommended dose of NOR is 10–75 mg qhs [7•].

## **Antiepileptics**

### *Valproates*

The VALPs consist of valproic acid, sodium valproate, and some combination of these drugs. They strongly block the peripheral and central trigeminovascular responses and nociceptive transmission, exert a great influence on the cortical neuronal hyperexcitability and suppress cortical spreading depression via the GABA-A receptor [37, 38].

A prospective randomized clinical trial in which PROP and sodium valproate were compared as concerns their efficacy in preventive migraine treatment in children and adolescents found no significant difference between these two drugs in mean headache duration per week, in headache severity, or in the complete cessation of headache attacks. The mean headache frequency per month was lower in the PROP group than in the sodium valproate group. As regards the side-effects, there was no significant difference between the two drugs [39]. Doses of 15–20 mg/kg/day appear to be effective. The common AEs of VALPs are somnolence, skin rash, weight gain, tremor, drowsiness, hair loss, and hematological or liver abnormalities [40, 41]. Due to their teratogenicity, VALPs cannot be recommended for females of reproductive age [20]. A recent meta-analysis focusing on the pharmacological preventive treatment of pediatric migraine indicated that VALPs were found ineffective in reducing the number of headaches per month [42]. The recommendation level of VALPs: Class IV, Level U [26••].

### *Topiramate*

As concerns migraine, TOP influences the pain transmission in the trigeminocervical complex and the third-order neurons in the ventroposteromedial thalamus [38].

A prospective clinical study concluded that a low prophylactic dose (<2 mg/kg/day) of TOP is effective in reducing the mean frequency, duration, and intensity of pediatric migraine [43].

A randomized comparative clinical trial demonstrated that TOP and PROP treatment displayed the same efficiency in reducing the headache frequency and the severity and duration of migraine attacks in childhood [44].

In a further clinical study, TOP proved effective (the monthly frequency, severity, and duration of migraine headache were all decreased) and safe for the prophylaxis of migraine in children [45]. A retrospective comparative trial revealed that the effects of FLUN and TOP did not differ significantly as concerns the total number of headache days per month in preadolescent and adolescent migraine patient groups with or without aura [46].

A recent review concluded that TOP is effective in decreasing the frequency of headaches in pediatric migraine patients

**Table 1** Prophylactic drugs recommended in pediatric migraine

| Drugs                             | Recommended daily dosage | Common adverse events   | Recommendation level |
|-----------------------------------|--------------------------|---|----------------------|
| Antidepressants                   |                          |   |                      |
| Amitriptyline                     | 10–150 mg qhs            | Dizziness, constipation, increased appetite, weight gain  | Class IV<br>Level U  |
| Nortriptyline                     | 10–75 mg qhs             | Cardiac (arrhythmia)  | No data              |
| Antiepileptics                    |                          |   |                      |
| Valproates                        | 15–20 mg/kg/day          | Somnolence, skin rash, weight gain, tremor, drowsiness, hair loss, hematological or liver abnormalities | Class IV<br>Level U  |
| Topiramate                        | 1–10 mg/kg/day           | Numbness, weight loss, cognitive impairment, fatigue, nausea, somnolence                                | Class IV<br>Level U  |
| Levetiracetam                     | 500–1500 mg bid          | Somnolence, fatigue, irritability, dizziness  | Class IV<br>Level U  |
| Zonisamide                        | 100–600 mg/day           | Dizziness, nausea, irritability, somnolence   | Class IV<br>Level U  |
| Gabapentin                        | 300–1200 mg tid          | Sedation, ataxia, fatigue, peripheral edema   | Class IV<br>Level U  |
| Antihistamines                    |                          |   |                      |
| Cyproheptadine                    | 0.25–1.5 mg/kg/day       | Sleepiness, weight gain, increased appetite   | Class IV<br>Level U  |
| Beta-adrenergic receptor blockers |                          |   |                      |
| Propranolol                       | 2–4 mg/kg/day            | Hypotension, depression, dizziness  | Class II<br>Level U  |
| Calcium ion channel antagonists   |                          |   |                      |
| Flunarizine                       | 5–10 mg qhs              | Sedation, weight gain, fatigue, gastrointestinal discomfort   | Class I<br>Level B   |
| Onabotulinum toxin A              | 100 units                | Redness or temporary pain at the injection site, ptosis, blurred vision                                 | Class IV<br>Level U  |
| Nutraceuticals (herbal products)  |                          |   |                      |
| Petasites hybridus (butterbur)    | 50–150 mg/day            | Burping   | Class II<br>Level U  |

Abbreviations: *qhs* every night at bedtime, *bid* twice daily, *tid* three times daily  
Modified from Ref. [7•, 21••, 26••]

[47]. A  $\geq 50$  % reduction in migraine rate was attained in 83–95 % of the patients. The recommended dose of TOP is 1–10 mg/kg/day, with a general dose of 50 mg bid (twice per day) [7•]. TOP is well tolerated; its common AEs are numbness, weight loss, cognitive impairment (affecting the verbal fluency, concentration, and working memory), fatigue, nausea, and somnolence [48]. The recommendation level of TOP: Class IV, Level U [26••].

#### Levetiracetam

LEV is a pyrrolidone derivative with an antiepileptic effect. It has a novel and apparently unique mechanism of action, which may be associated with its binding to

synaptic vesicle protein SV2A therefore influencing the neurotransmitter release [49].

An early small retrospective study on the efficacy of LEV in pediatric migraine pointed to its beneficial effect (in 10 of 19 children and adolescents, LEV eliminated the migraine headache) [50]. An open label study led to the conclusion that LEV reduced the frequency of migraine: a more than 50 % decrease in the frequency of monthly headaches and was achieved (in 18 of 20 patients), and the Pediatric Migraine Disability Assessment Test (PedMIDAS) revealed a significant decrease in disability as compared with the baseline in pediatric migraineurs [51]. The recommended daily dose of LEV is 500–1500 mg bid [7•, 21••]. Its safety profile appears

acceptable, but its common AEs include somnolence, fatigue, irritability, and dizziness [7•, 21••, 26••]. The recommendation level of LEV: Class IV, Level U [26••].

### *Zonisamide*

ZON is a synthetic 1,2-benzisoxazole-3-methanesulfonamide, which acts by inhibiting the voltage-sensitive sodium and reducing the voltage-sensitive T-type calcium channels [52].

A very small retrospective study suggested that ZON had the capability to reduce the headache frequency in refractory pediatric headache patients (8 of 12 patients responded favorably) [53]. The recommended dose of ZON is 100–600 mg per day [7•, 21••]. Its common AEs are dizziness, nausea, irritability, and somnolence [7•, 21••]. The recommendation level of ZON: Class IV, Level U [26••].

### *Gabapentin*

GBP is structurally related to GABA, but without any direct effects on GABA or any of its receptors [54]. There have been only very rare clinical studies of GBP in pediatric migraine. Belman et al. reported data on 18 migraine children treated with GBP, 80 % of whom attained a more than 50 % reduction in migraine frequency [21••, 55]. The recommended dose of GBP is 300–1200 mg three times daily (tid) [21••]. The common AEs of GBP are sedation, ataxia, fatigue, and peripheral edema [21••]. The recommendation level of GBP: Class IV, Level U [26••].

## **Antihistamines**

### *Cyproheptadine*

CYP exerts antihistaminergic, antiserotonergic, and anticholinergic actions and has the ability to block (competitively and reversibly antagonize) the histamine and serotonin receptors [56]. The 5-hydroxytryptamine 1B and 1D receptors take part in the activation of the trigeminovascular system via cerebrovascular vasoconstriction and inhibition of the release of vasoactive neuropeptides, e.g., calcitonin gene-related peptide (CGRP), SP, and pituitary adenylate cyclase-activating polypeptide (PACAP) [2••, 19, 57, 58].

In a double-blind controlled study in which patients aged 16 to 53 years (mean 28.6) received CYP as prophylactic treatment of migraine, the mean headache frequency decreased from 8.4 to 3.7 per month, with an overall positive response rate of 83 % [59]. A recent retrospective clinical study led to the finding that CYP was effective in abdominal migraine and in cyclic vomiting syndrome (among the functional gastrointestinal disorders), the responder rate proving to be high: in abdominal migraine 13

of 18 pediatric patients (72 %) and in cyclic vomiting syndrome 6 of 8 patients (75 %) exhibited a clinical improvement [60]. CYP is available as tablets and liquid suspensions, with recommended doses of 0.25–1.5 mg/kg/day [21••]. The most common side-effects of CYP are sleepiness, weight gain, and increased appetite [7•, 34, 60]. An investigation by a large academic children's hospital of the prescription patterns in patients aged 2–17 years demonstrated that the one of the most common by prescribed medications for pediatric migraine prophylaxis was CYP [29]. The recommendation level of CYP: Class IV, Level U [26••].

## **Beta-Adrenergic Receptor Blockers**

### *Propranolol*

PROP, a nonselective beta-adrenergic receptor blocker that inhibits the third-order trigeminovascular nociceptive neurons in the ventroposteromedial nucleus of the thalamus [20, 61], has a long history of use in migraine prophylaxis in children [62]. The results emerging from clinical trials have been conflicting [1, 26••].

In recent studies, PROP has been widely used as a comparative pharmac.

In a prospective randomized trial which compared the prophylactic anti-migraine effects of PROP and VALP in children (aged 5–15 years) with migraine without aura, VALP was found to be superior to PROP only in reducing the mean headache frequency per month [39]. Low-dose PROP and low-dose AMI proved equally effective in reducing the frequency of severe migraine attacks in pediatric migraineurs (mean age 12.54 years), but it was noteworthy that PROP had fewer side-effects [30]. A randomized clinical comparative trial relating to childhood migraine prophylaxis revealed that TOP and PROP displayed the same efficacy in reducing the frequency, severity, and duration of migraine attacks [44]. In contrast, another parallel single-blinded randomized clinical trial involving 5–15-year-old migraineurs revealed that TOP was more effective than PROP in reducing the monthly frequency, severity, and duration of headache and in the PedMIDAS score. Both drugs exerted transient and mild side-effects [63]. A recent comparative randomized controlled trial that focused on the effects of PROP as compared with pregabalin in pediatric migraine led to the result that pregabalin reduced the headache frequency considerably more effectively than did PROP [64].

The recommended dose of PROP is 2–4 mg/kg/day. The most common side-effects are hypotension, depression, and dizziness [7•, 21••]. The unfavorable AEs of PROP have limited its wide-ranging use in young migraineurs [26••]. The recommendation level of PROP: Class II, Level U [26••].

## Calcium ion Channel Antagonists

### *Flunarizine*

FLUN is a nonselective calcium ion entry blocker that mainly acts via T-type ion channels [65]. Its exact mechanism of action in migraine is still unknown, but it may involve smooth muscle inhibition in the vasculature and effects on neuronal activation via 5-hydroxytryptamine antagonism [66].

A classical double-blind, placebo-controlled, crossover study revealed that FLUN was effective in the prophylaxis of childhood migraine [67].

A single-center retrospective observational study which evaluated the effects of FLUN in various subtypes of childhood migraine, i.e., migraine without aura, migraine with aura, sporadic, and familial hemiplegic migraine, found that FLUN was more effective in the hemiplegic migraine group [68].

With the focus on disability and the quality of life of pediatric migraineurs, FLUN treatment significantly decreased the PedMIDAS score, but in the same study, FLUN was inferior to TOP and PROP in the PedMIDAS system [69].

The recommended dose of FLUN is 5–10 mg qhs [7•, 21••]. The common AEs of FLUN are sedation, weight gain, fatigue, and gastrointestinal discomfort [7•, 21••, 26••].

The recommendation level of FLUN: Class I, Level B [26••].

### **Onabotulinum Toxin A**

One of the latest therapeutic regimes for adult migraine patients is OBOT-A injection treatment, which was approved by the US Food and Drug Administration in 2010 [70, 71].

Botulinum neurotoxin-A is a purified neurotoxin complex produced by the anaerobic bacterium *Clostridium botulinum* [72, 73]. The main mechanism of action of botulinum toxin involves the targeting of the neuromuscular junctions by means of a specific cleavage of the soluble N-ethylmaleimide-sensitive factor (NSF)-attachment protein receptor complex (SNARE)-like synaptosomal-associated protein of 25 kDa (SNAP-25) [72, 73]. The final outcome of this multistage process is the breaking of pain neurotransmission, including the inhibition of the release of migraine-related neuropeptides (e.g., CGRP and SP) and glutamate [72–75].

The prevalence of chronic migraine among pediatric migraineurs is around 3 % [24]. A retrospective case series study of the use of OBOT-A for the treatment of refractory pediatric chronic daily headache, including chronic migraine, revealed that four of ten patients reported a decrease in headache intensity and two of them decrease in headache frequency, and these four responder patients achieved a favorable improvement of the quality of life [22]. A retrospective review of the data on 45 pediatric chronic daily headache patients

who participated in 252 OBOT-A injections (average dose  $188.5 \pm 32$  units) concluded that the monthly headache frequency was decreased and the PedMIDAS score showed an improvement [24]. A recent small case series study of chronic migraineurs (aged 13–17 years) showed a good responder rate (seven of ten patients). The number of headache days per month decreased from 19.2 to 10.1 [23]. The recommended dose of OBOT-A is 100 units. The common AEs of OBOT-A are redness or temporary pain at the injection site, ptosis, and blurred vision [26••]. The recommendation level of OBOT-A: Class IV, Level U [26••].

### **Nutraceuticals (Herbal Products)**

#### *Petasites Hybridus (Butterbur)*

Extracts of the roots of *Petasites hybridus* exert an anti-inflammatory effect via the inhibition of leukotriene production and influence intracellular calcium accumulation through the L-type voltage-gated calcium ion channels [76].

A multicenter prospective open-label study with a butterbur root extract for migraine prevention (50–150 mg for 4 months), which involved 108 children and adolescents (aged 6–17 years), resulted in 77 % of all patients reporting a 63 % decrease in frequency of migraine attacks [77]. A prospective, randomized, partly double-blind, placebo-controlled, parallel-group trial was set up to examine the prophylactic antimigraine effects of butterbur root extract and music therapy in primary school children [78]. The evaluation of this study revealed that both the butterbur extract and music therapy were superior to placebo in reducing the frequency of headache attacks in the follow-up period [78]. The recommended dosage of butterbur is 50–150 mg per day. The main AE of butterbur extract is burping. The recommendation level of *Petasites*: Class II, Level U [26••].

## **Conclusion**

The pathomechanism of migraine is not fully understood and personalized therapy tailored to the patient is therefore not available for pediatric migraine. A further difficulty is the fact that the latest therapeutic guidelines were published more than 10 years ago. This review has surveyed the latest literature data relating to the prophylactic drugs used in the daily clinical practice in children and adolescents with migraine. For the near future, basic experimental and human headache research is needed, such as innovative pharmaceutical investments with fully humanized monoclonal antibodies against CGRP and CGRP receptors. Randomized clinical trials are still necessary as regards currently used prophylactic antimigraine drugs and new compounds designed for the treatment of young

migraineurs. Overall, new therapeutic guidelines are clearly required in this field.

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#### Compliance with Ethical Standards

**Conflict of Interest** János Tajti, Délia Szok, Anett Csáti, and László Vécsei declare that they have no conflict of interest.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

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- Of importance
- Of major importance

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